2004

Cost Estimation (OA 4702)

Nussbaum, Dan

Cost Estimation
(OA 4702)

Professor Dan Nussbaum
Department of Operations Research
Glasgow 242
656-2387
dnussbaum@nps.edu

Course Overview

- **Syllabus**
- **What is Cost Analysis?**
- **How are Cost Estimates used?**
- **Why do we care?**
- **Overview of this course.**

Syllabus

OA 4702- Cost Estimation- Winter 2005			
Date	**Lecture**	**Topic**	**Reading**
5-Jan	1	Syllabus, Overview of Cost Analysis	Chapter 1
6-Jan	2	Overview of Cost Analysis	
10-Jan	3	The Cost Estimating Process	Chapter 2
11-Jan	4	The Cost Estimating Process	
12-Jan	5	Data Sources and Data Normalization	Chapter 3
13-Jan	6	Data Normalization	Chapter 4
17-Jan	**Holiday—MLK Day**		
18-Jan	7	Data Normalization, Inflation/Escalation Exercise	
19-Jan	8	Cost Modeling Process	Chapter 5
20-Jan	9	Univariate Statistics	Chapter 6
24-Jan	10	Univariate Statistics	Chapter 6
25-Jan	11	Simple Linear Regression	Chapter 7
26-Jan	12	Simple Linear Regression	
27-Jan	13	Simple Linear Regression	
31-Jan	14	Multivariate Linear Regression	Chapter 8
1-Feb	15	Intrinsically Linear Regression	Chapter 9
2-Feb	16	Cost (Learning) Improvement Curves	Chapter 17
3-Feb	17	Cost (Learning) Improvement Curves	
7-Feb	18	Cost (Learning) Improvement Curves	
8-Feb	19	Cost (Learning) Improvement Curves	
9-Feb	20	Cost (Learning) Improvement Curves	
10-Feb	21	Mid-term Review	
14-Feb	22	Mid-term ExamReview	
15-Feb	23	Analogy Technique	Chapter 11
16-Feb	24	Expert Opinion, Cost Factors, and Wrap Rate Techniques	Chapter 12, 13, 14
17-Feb	25	Expert Opinion, Cost Factors, and Wrap Rate Techniques	
21-Feb	**Holiday--President's day**		
22-Feb	26	Time Phasing the Cost Estimate	Chapter 16
23-Feb	27	Time Phasing the Cost Estimate	Chapter 16
24-Feb	28	Risk and Uncertainty	
28-Feb	29	Risk and Uncertainty	
1-Mar	30	Capital Planning and Time Value of Money	
2-Mar	31	Capital Planning and Time Value of Money	
3-Mar	32	Capital Planning and Time Value of Money	
7-Mar	33	Capital Planning and Time Value of Money	
8-Mar	34	Integrated Work Project	
9-Mar	35	Integrated Work Project	
10-Mar	36	Integrated Work Project	
14-Mar	37	Software Cost Estimating	
15-Mar	38	Software Cost Estimating	
16-Mar	39	Review and Wrap Up	
17-Mar	40	Review and Wrap Up	
21-Mar	**Final Exam**		

What is Cost Analysis?

- **Cost Estimating: The process of collecting and analyzing historical data and applying quantitative models, techniques, tools, and databases to predict the future cost of an item, product, program or task. The art of approximating the probable worth (or cost) extent, or character of something based on information available at the time.**
- **Cost estimate is an analysis of individual cost elements using established methodologies to project from data to estimated future costs**
- **Purpose of cost estimating**
  - **Translate system/functional requirements associated with programs, projects, or processes into budget requirements**
  - **Determine and communicate a realistic view of the likely cost outcome, which can form the basis of the plan for executing the work**

What is Cost Analysis?

“The art of weapon system cost estimating. It involves using incomplete, inaccurate, and changing data of an outmoded & ineffective weapon system to derive the precise cost of purchasing an unknown quantity of an undefined weapon to satisfy an overly exaggerated & unvalidated requirement at some time in the future, under uncertain conditions, with a minimum of funds.”

What is Cost Analysis?

What is Cost Analysis?

- **It is an "Estimation of Costs"**
- **An analytical effort directed at calculating/projecting the future cost of weapon systems – both an Art and a Science**
  - **Incorporates several quantitative analysis techniques:**
    - » **Data Collection and Analysis**
    - » **Regression Analysis**
    - » **Learning Curves**
    - » **Risk Analysis**
- **Involves Micro and Macro views of a program**
  - **Must understand from a micro-perspective how each cost element relates to another – This is half the work!!**
  - **Must also understand total cost implications**
- **Requires interaction with engineers, logisticians, schedulers, all people involved in the program.**

How Are Cost Estimates Used?

- **Used as a source of resource information for planning purposes**
  - **Provides a quantitative basis for management decisions regarding optimal allocation of resources**

- **A cost analyst helps to decide which of the possible alternatives is more desirable and recommends a course of action that will steer decision makers towards it and away from undesirable alternatives**
  - **Used as "*financial advice*"**
    - » **Budget decisions**
    - » **Program Managers**

Purposes of cost estimating

- Translate system/functional requirements associated with programs, projects, or processes into budget requirements
- Determine and communicate a realistic view of the likely cost outcome, which can form the basis of the plan for executing the work
- Develop a source of resource information for planning purposes

•Cost estimating, as part of a total systems analysis, provides an analytic underpinning to support decision makers.

•A cost analyst helps to decide which of the possible alternatives is more desirable and recommends a course of action that will steer decision makers towards it and away from undesirable alternatives.

Budgeting

Fee for Service

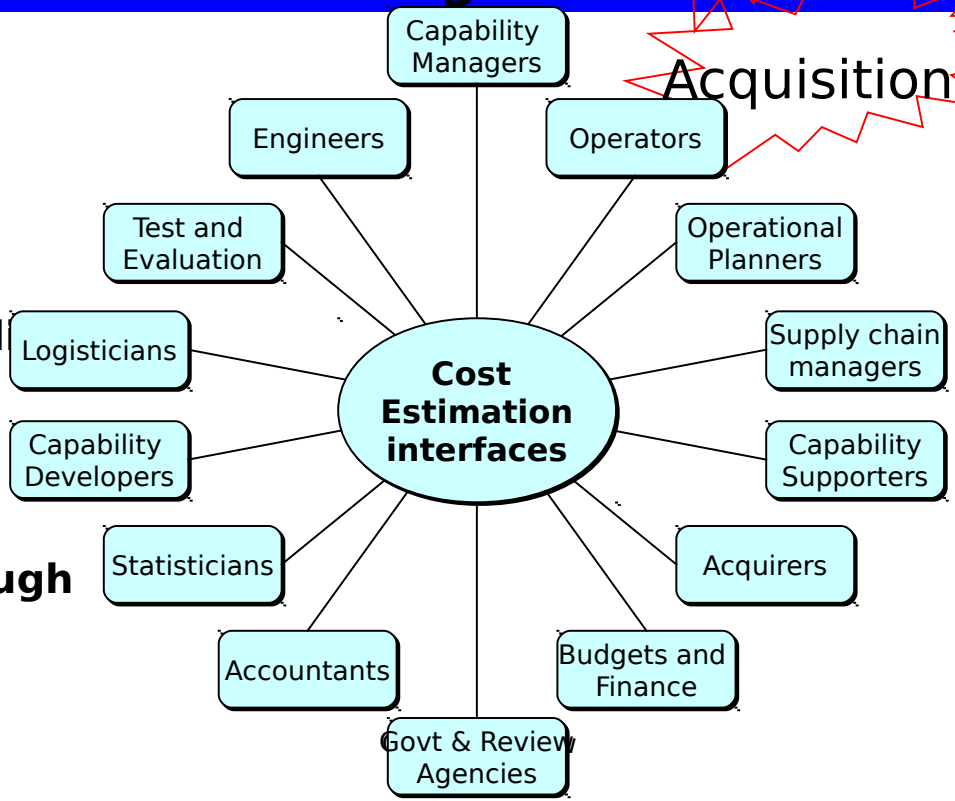
ROI

Strategic planning

Acquisition

When is Cost Analysis and Estimating Done

- **Budget development, justification, execution**
- **Program development and justification**
- **Balance of Investment studies of future force mix**
- **Selection of equipment through AoAs**
- **Efficient management through equipment life cycle**



These applications demand different types of forecasts, generated with the different levels of detail available at the relevant stage in the equipment's life cycle.

Why is Cost Estimating Done?

- **Make decisions on program viability, structure, and resource requirements**
- **Establish and defend budgets**
- **Assess technology changes**
- **Provide basis for evaluating competing systems and /initiatives (cost/benefit analyses and AoAs)**
- **Conduct analysis of alternatives (AoA)**
- **Perform source selection**
- **Perform design trade-offs**
- **Comply with public law**
- **Satisfy oversight requirements**
- **Identify and objectively quantify the impact of program risks (technical and schedule risks)**
- **Evaluate proposals for cost reasonableness**

Cost estimating, as part of a total systems analysis, provides an analytic underpinning to support decision makers.

As part of a total systems analysis, cost estimating helps decision makers to:

- **Make decisions on program viability, structure, and resource requirements**
- **Establish and defend budgets**
- **Assess technology changes**
- **Provide basis for evaluating competing systems and /initiatives (cost/benefit analyses and AoAs)**
- **Conduct analysis of alternatives (AoA)**
- **Perform source selection**
- **Perform design trade-offs**
- **Comply with public law**
- **Satisfy oversight requirements**
- **Identify and objectively quantify the impact of program risks (technical and schedule risks)**
- **Evaluate proposals for cost reasonableness**

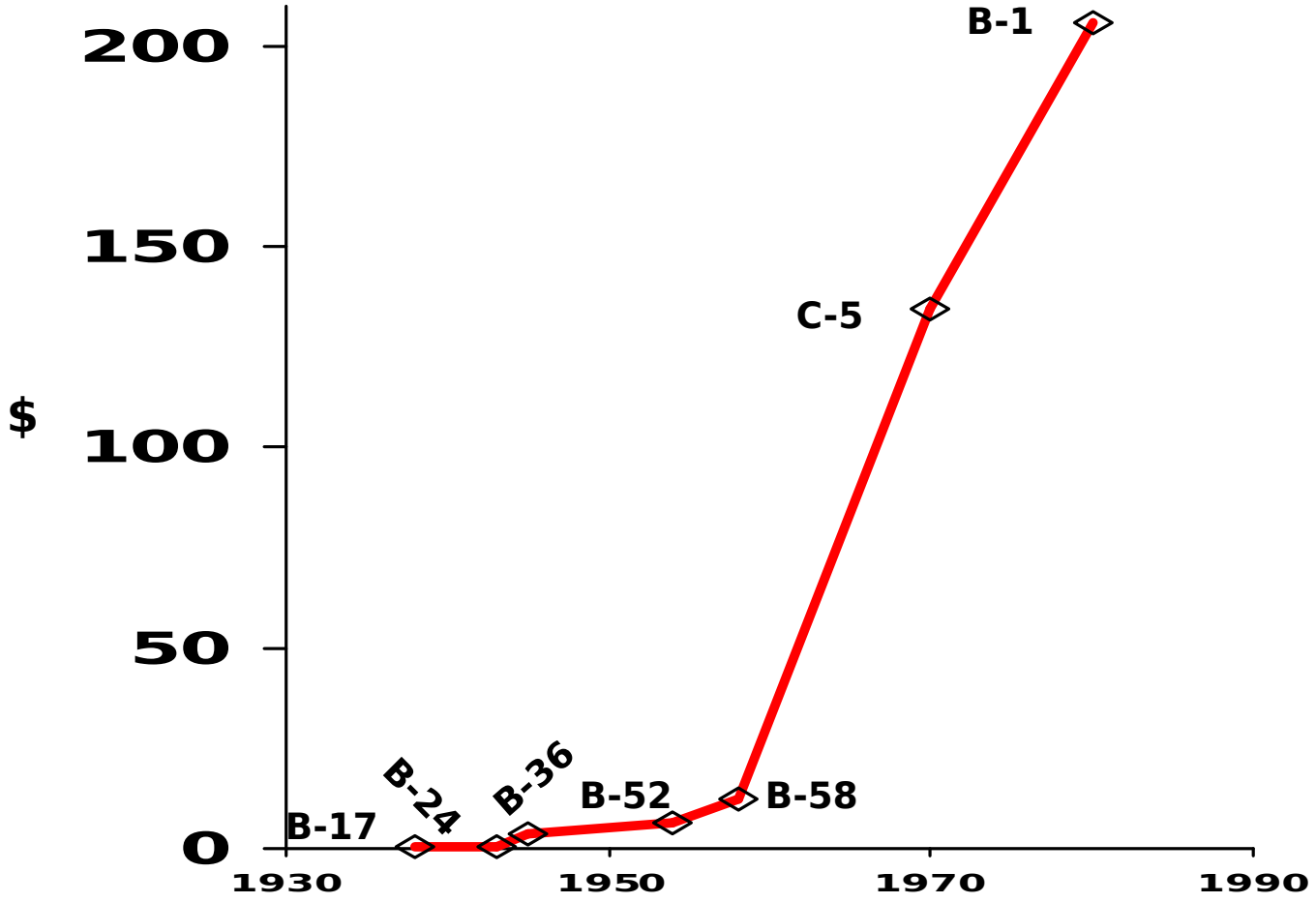
Why Do We Care?

- **DOD Directive 5000.1 and DOD Instruction 5000.2 specify the policy and procedures to be used during the acquisition of weapons systems**
  - **Cost estimates are <u>required</u> in the Acquisition Process**

- **Resources are increasingly scarce and weapons systems are increasingly expensive**
  - **With budgets decreasing and costs increasing, <u>informed</u> <u>decisions</u> are critical!**
  - **-- Estimating errors today are much more dangerous than**

    in the past –- (example: A-12 program)

Unit Cost Trends



DoD Cost Estimating – The Basics

- **Program Manager is responsible for preparation of program office cost estimate**
- **Military service reviews program office cost estimate and forms a Service Cost Position**
- **An independent cost estimate is required for all major defense acquisition programs**
  - **OSD CAIG estimate for programs of interest to SECDEF**
  - **Service cost agency estimate for other programs**
- **The service cost position and the independent estimates are presented to the Defense Acquisition Executive and the Defense Acquisition Board**

Statutory and Regulatory Bases for DoD Cost Estimates

- *USC Title 10, Section 2432:*

  The SecDef shall report a full life cycle cost for each major defense acquisition program (MDAP) ……

- *USC Title 10, Section 2434:*

  The SecDef may not approve SDD, or the production and deployment, of a MDAP unless an independent estimate of the full life-cycle of the program … [has] been considered by the Secretary.

  … the independent estimate … [shall] -- (a) be prepared by an office or other entity that is not under … the military department … directly responsible for … [developing or acquiring] the program; and (b) include all costs …. without regard to funding source or management control …

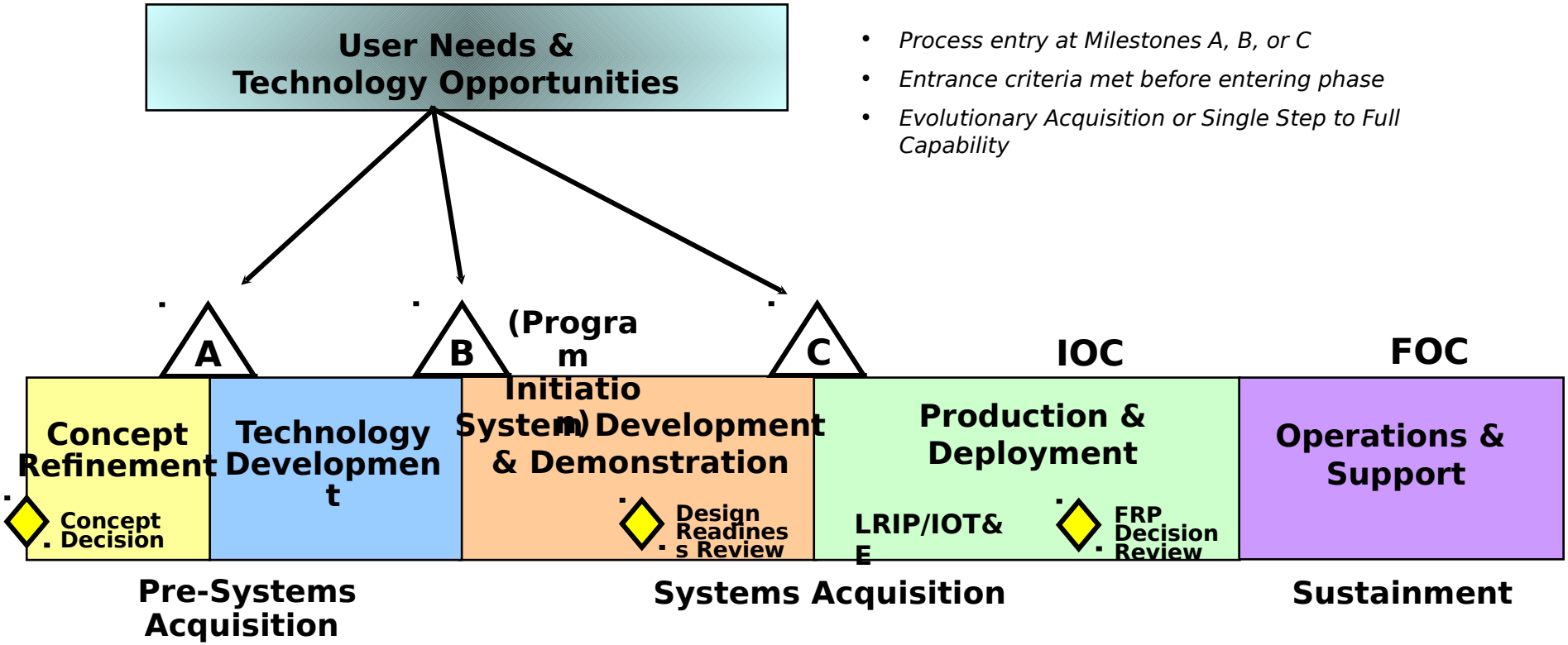
- *DoDI 5000.2:*

  …**the CAIG shall prepare an independent life-cycle cost estimate and report for all milestone reviews after Milestone A (Program Initiation/Milestone B & C).**

- *DoD Directive 5000.4:*

  … the OSD CAIG is chaired by the Deputy Director, Resource Analysis, in the Office of the Director, Program Analysis & Evaluation.

Acquisition Process: The New DoD 5000 Model



- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*

Acquisition Categories

Category	Criteria (FY00$)	Designation Authority	Milestone Decision Authority
ID MDAP	> $365M RDTE or > $2.19B Proc or so designated by USD(AT&L)	USD(AT&L)	USD(AT&L)
IC MDAP	same	USD(AT&L)	ASN(RD&A)
IAM MAIS	> $378M Lifecycle > $126M Proc > $31.5M Single Year	ASD(C3I)	ASD(C3I)
IAC MAIS	same	ASD(C3I)	ASN(RD&A)

Overview of this Course

$$\text{Future Cost} = f(\text{Historical Cost})$$

Why Cost *Analysis*?

- **Each Cost Estimate is different**

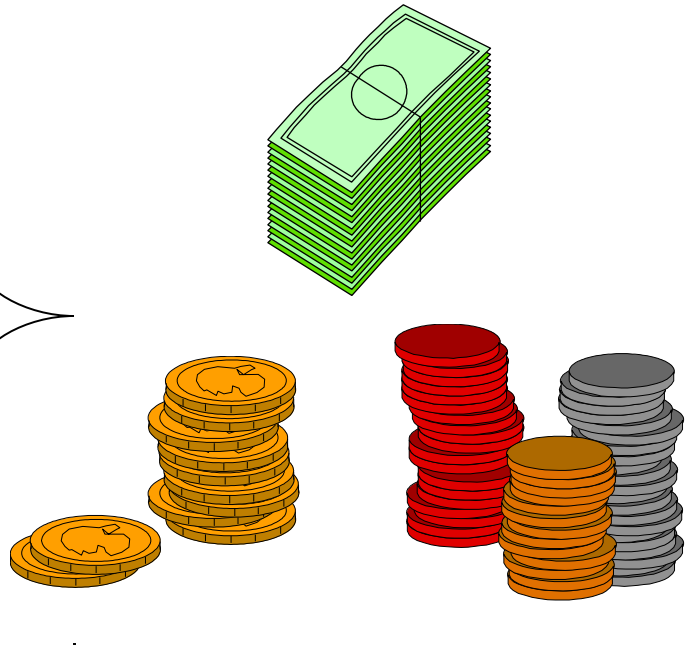
  -- Truly an Art
- **Each requires a refined methodology**

  -- There are no “Black boxes”
- **Each requires planning, insight, judgment and analysis of its own.**
- **The previous cost categories have a lot of uncertainty, so we look at historical program costs to help us predict these costs for future weapon systems.**

What do we mean by *Cost*?

- **Manpower**
- **Hardware**
- **Training**
- **Program Management**
- **Systems Engineering**
- **Etcetera…**

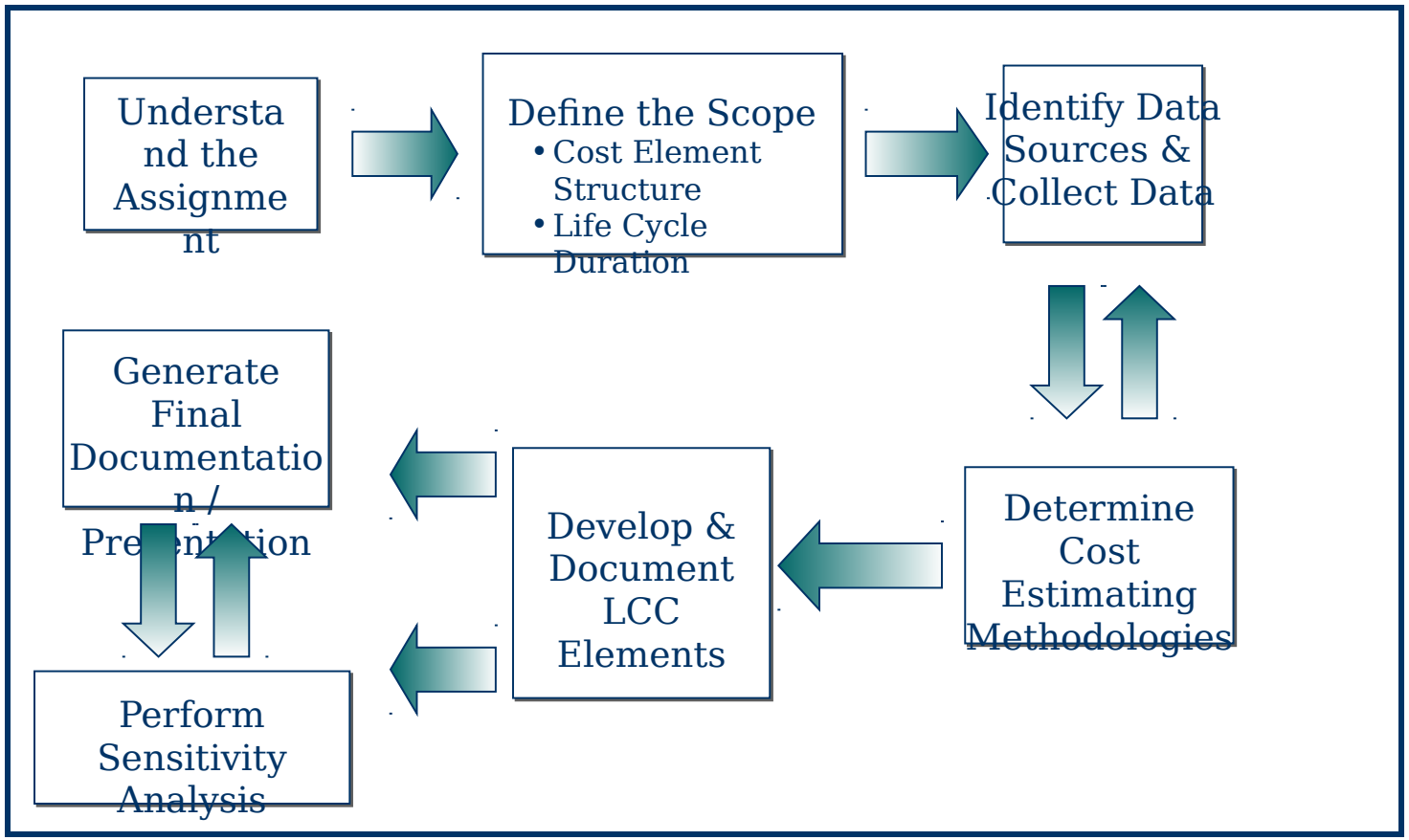
- **No Matter What the Resource, it all boils down to $$$$$$$$$$**



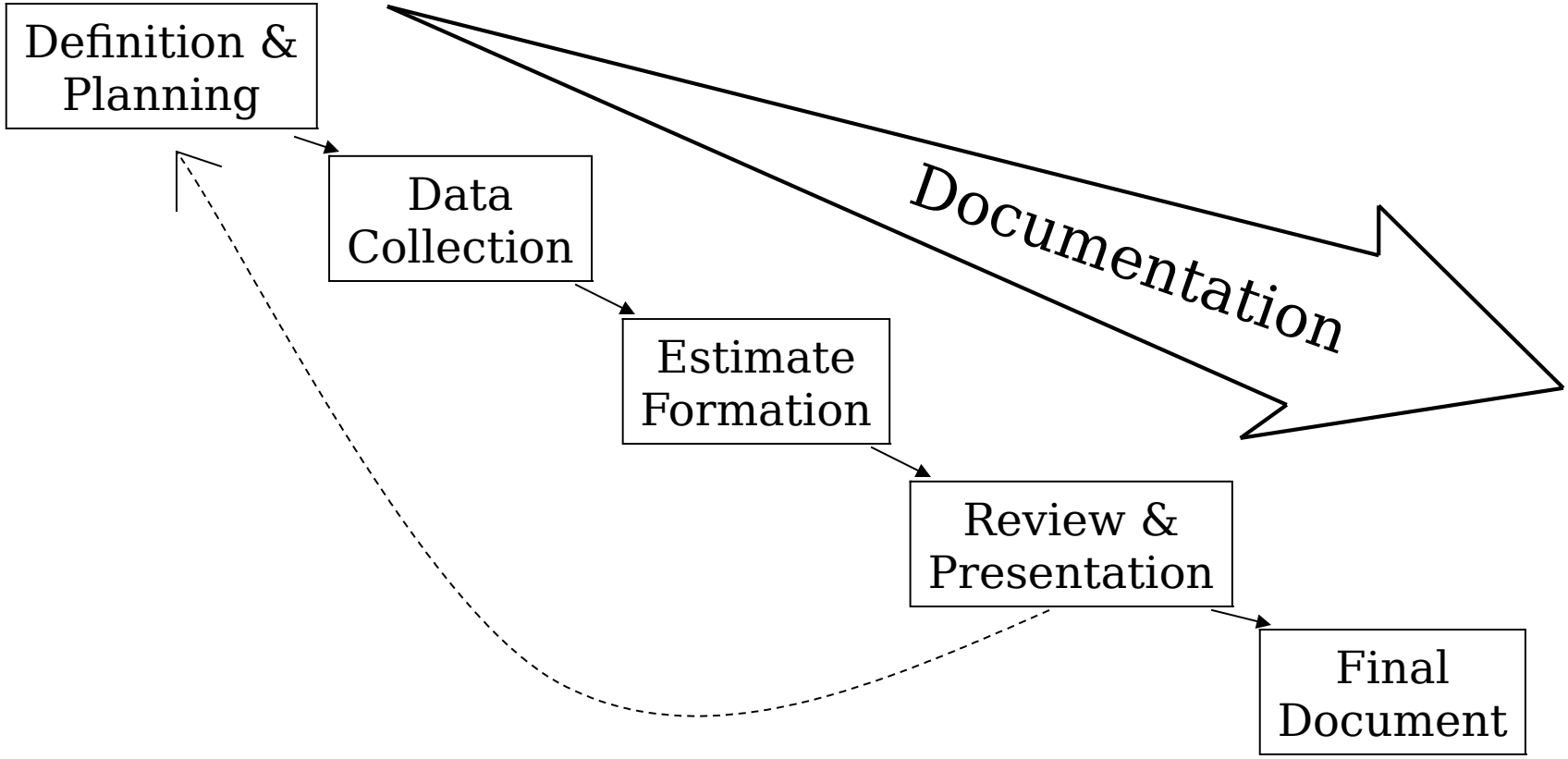
Scope of the DoD Cost Estimates

- Full Life Cycle Costs- all phases and elements of weapon systems
  - Research Development Test & Evaluation
  - Hardware and Software
  - Supporting Data, Equipment, Training
  - Initial Spares
  - Military Construction (MILCON)
  - Modifications
  - Operations and Support Over System Life
    - Including Manpower
  - Environmental Cost -
    - Compliance, Demilitarization, Clean-Up, Disposal
- Regardless of Funding Appropriation or Source
- Based Upon Program Described in the Cost Analysis Requirements Description (CARD)

LCCE Process



The Cost Estimating Process



Related Subjects We Will Discuss

- Types of Estimates
- Normalizing Data
- Work Breakdown Structure
- Acquisition Milestone Process
- Selecting Estimating Methodologies
- Software Development Costs
- Risk and Uncertainty Analyses
- Economic Analysis
- and many more...

Data Collection

- **Inherent Problems**
- **Data Sources**

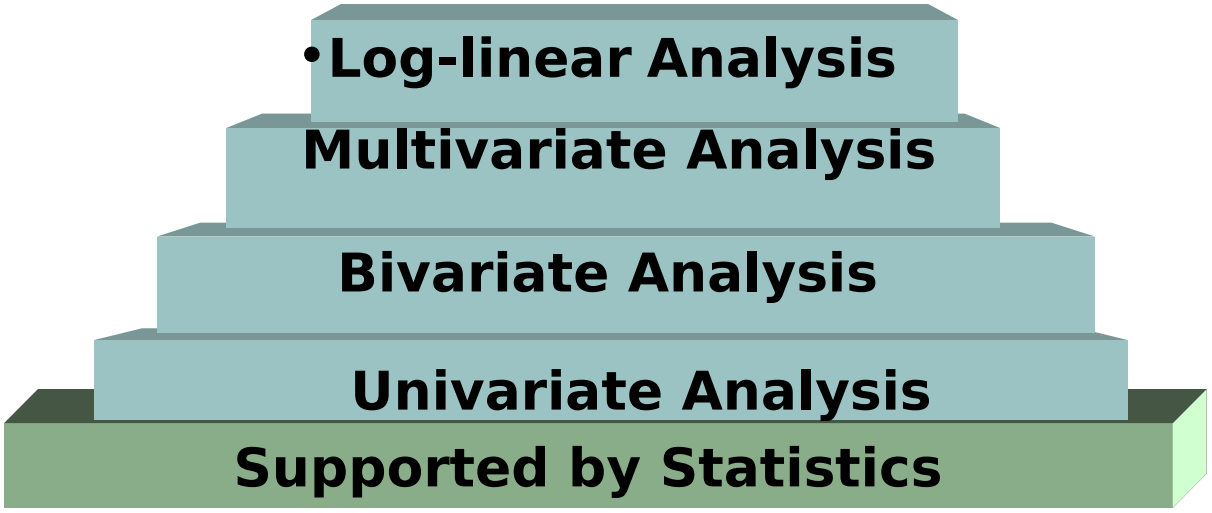
  -- Where to Find Them

  -- Internet
- **Data Normalization**

  -- Compare “Apples-to Apples”

Parametric Cost Modeling

- **Parametric Cost Estimating Relationships**
  - **Cost = f (technical, performance, schedule)**



Non-Parametric Cost Modeling

- **Analogy**
- **Expert Opinion**
- **Engineering Buildup**
- **Cost Factors**
- **Extrapolation from Actuals**

Statistics

Standard Error?

t statistic?

F statistic?

Coefficient of Variation?

What do they REALLY mean?

Risk and Uncertainty

- **Risk Management**
- **Predicting Cost Uncertainty Probabilities**

  -- Cost not as a "Point Estimate", but as a

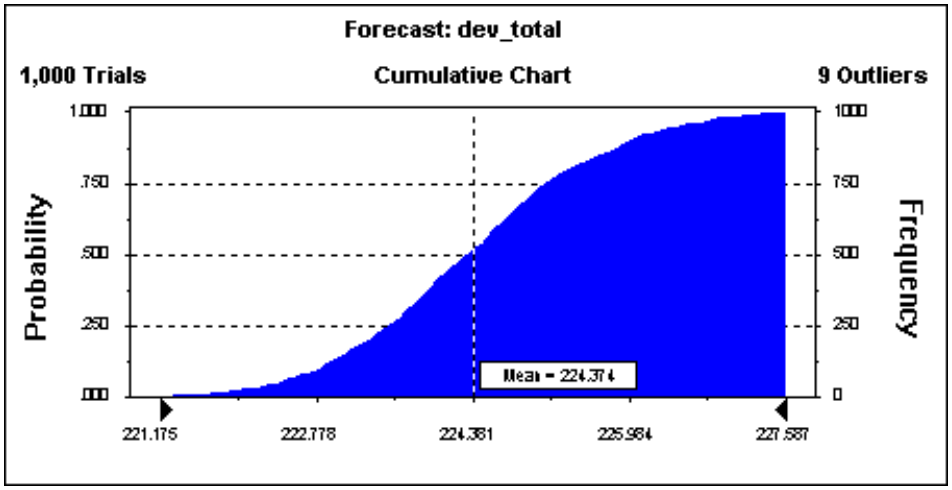
  Probability Distribution

  -- Comptroller: "How much do I budget to be 80% sure of having adequate funding?"

Cost Risk

- **A cost risk analysis presents the distribution of possible costs based on the probability that risk to individual elements may result in cost increases or decreases**
- **Cost risk is the inherent risk in estimating a Work Breakdown Structure (WBS) component due to variances in approaches, availability of data and schedule/performance risks associated with a program**

- **A cost risk analysis is modeled to compute the most likely cost for a project based on the individual cost probability distributions for WBS components**



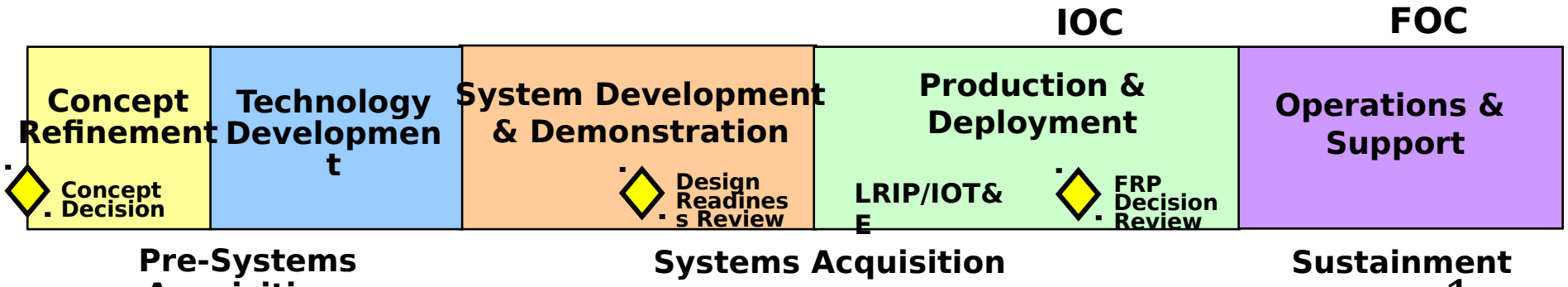
The Effect of Time

- **Time-Phasing Costs**

  -- How to “spread” cost over time?
- **Cost Improvement/Learning Curves**
- **Differences Between Development and Production Costs**
- **Production Rate**

The Life Cycle

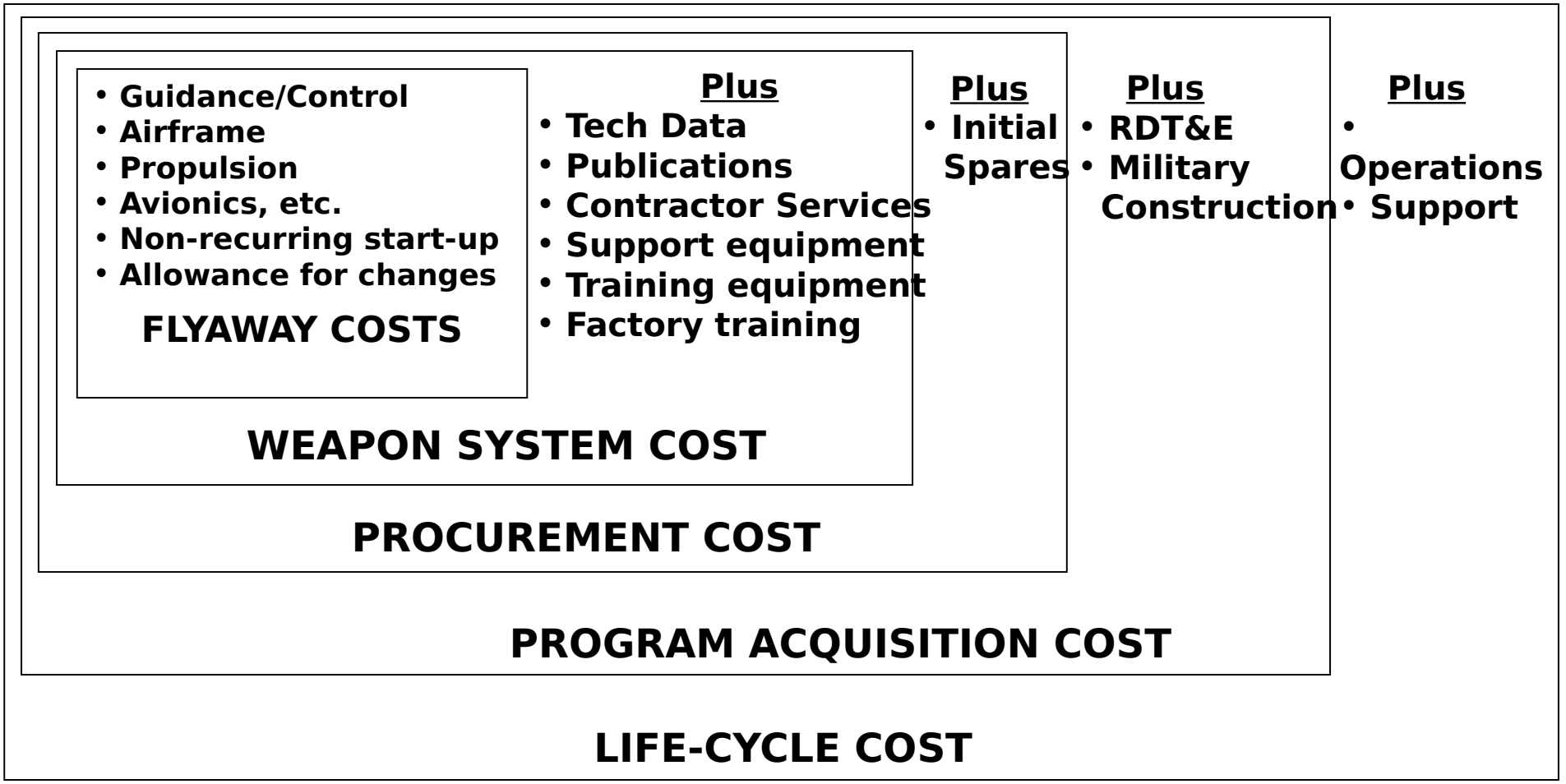
- **Components of Life Cycle Costs are related to project phases -**
  - **Concept studies - Feasibility studies**
  - **Project definition - Full development**
  - **Production investment - Production**
  - **Demonstration & acceptance - Operational investment**
  - **Operations - Support**
  - **Post & continuing design - Disposal**



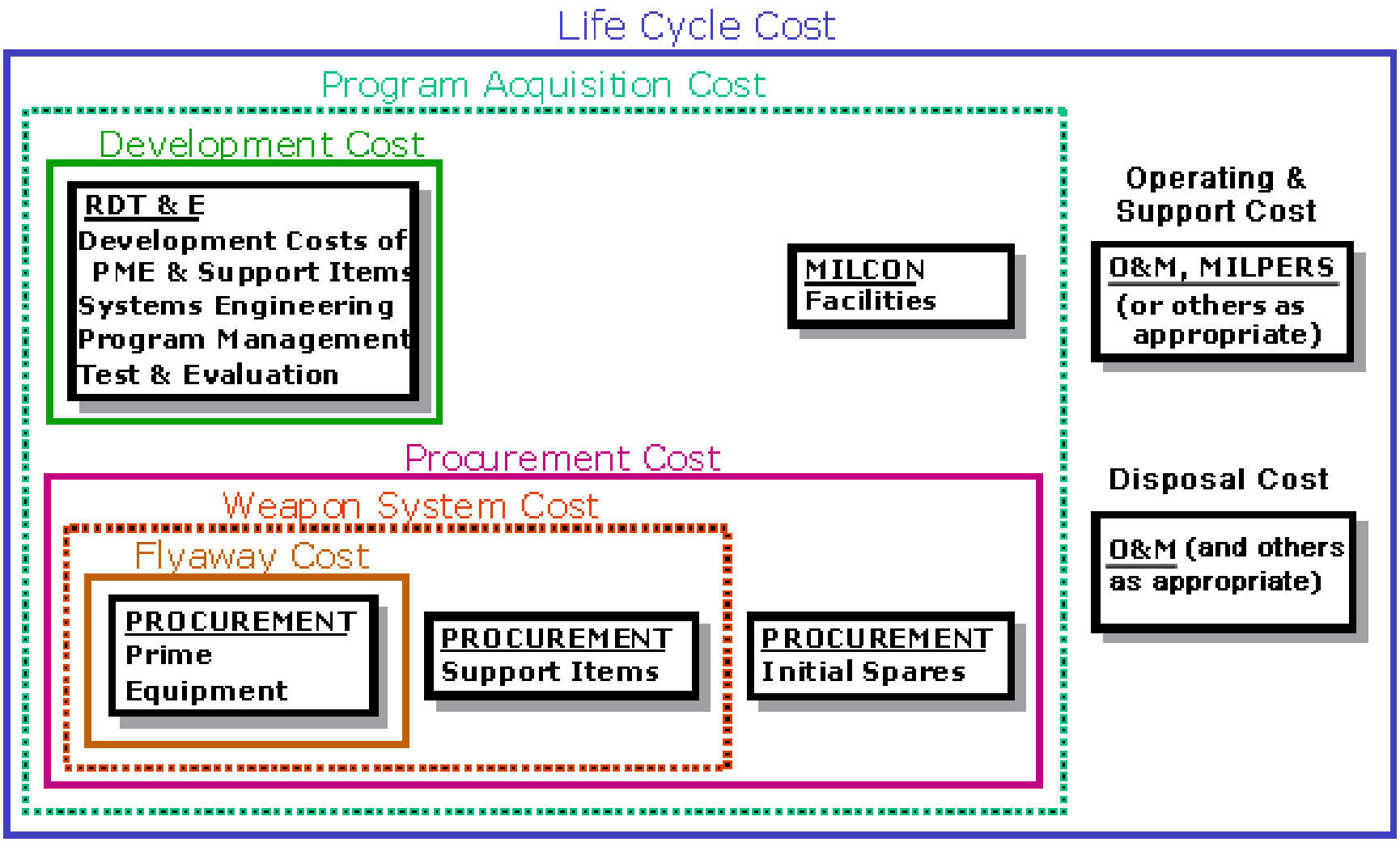
Life-cycle cost categories

- **These are categories commonly used by the Cost Analysis Improvement Group (CAIG). They are listed in DoD 5000.4-M, Cost Analysis Guidance and Procedures.**
- **Research &Development (R&D): Estimated cost of all program specific research and development.**
- **Investment: Estimated cost of the investment phase, including total cost of procuring the prime equipment; related support equipment; training; initial and war reserve spares; pre-planned product improvements and military construction.**
- **Operating and Support (O&S): Estimated cost of operating and supporting the fielded system, including all direct and indirect costs incurred in using the system, e.g., personnel, maintenance (unit and depot), and sustaining investment (replenishment spares). The bulk of life-cycle costs occur in this category.**
- **Disposal: Estimated cost to dispose of the system after its useful life. This includes demilitarization, detoxification, long-term waste storage, environmental restoration and related costs.**

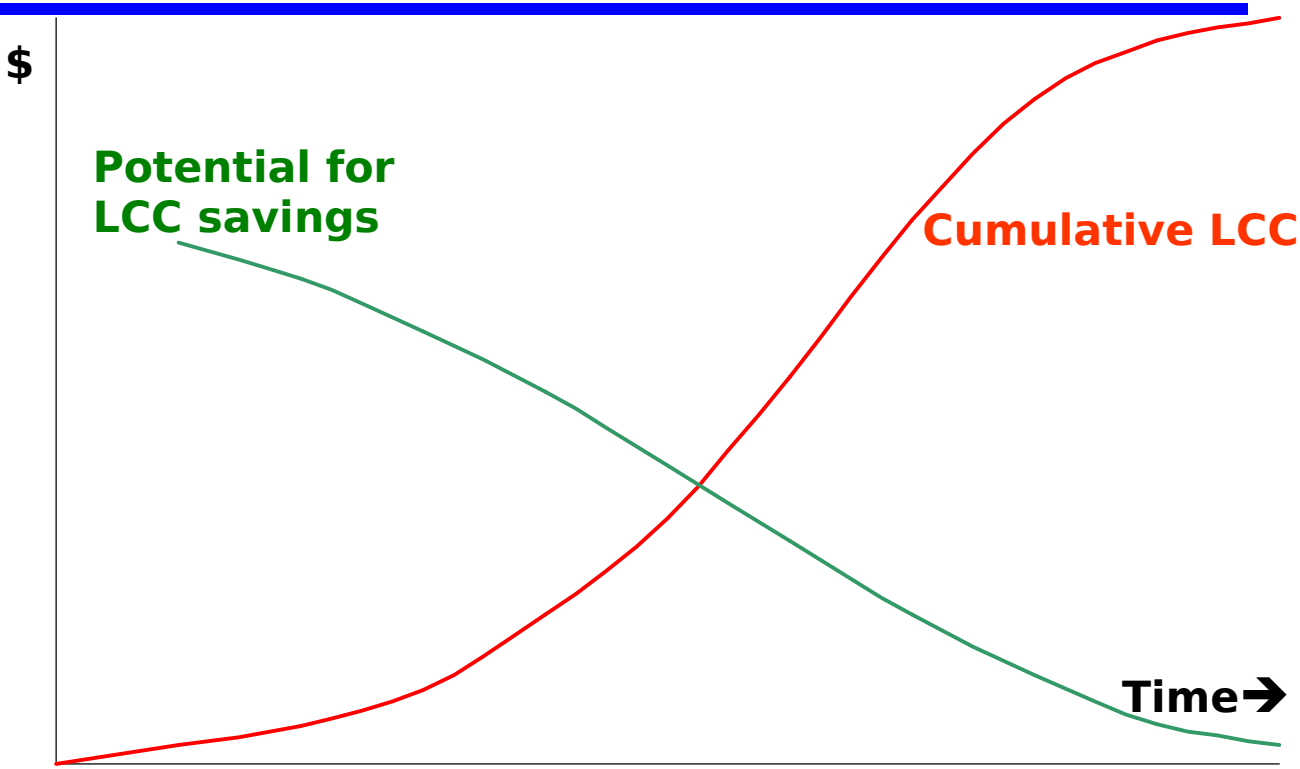
Life-Cycle Cost Composition



Life Cycle Cost Composition



Life-Cycle Phases and Their Relative Cost



			Life-Cycle Cost				
			RDT&E		Investment		Operations & Maintenance
		Applied Research Advanced Technology	Validation	EMD	Limited Production	Full Production	Deployment/ Operations
Assess Mission Need	Basic Research	Exploratory Development	Advanced Development	Engineering Development			
	Phase 0		Phase 1	Phase 2		Phase 3	Phase 4
			Acquisition Phase			Operation Phase	

Cost Terminology

- ***Recurring Costs*** **are those costs that are repetitive and occur when a company produces similar goods or services on a continuing basis. A fixed cost that is paid on a repeatable basis is a recurring cost (i.e., rent). For example, for a company that provides architectural services, office space rental - which is a fixed cost - is also a recurring cost. Can be tied to Quantity Produced.**

- ***Nonrecurring costs*** **are those costs that are not repetitive, even though the total expenditure may be cumulative over a relatively short period of time. Nonrecurring costs typically involve developing or establishing a capacity to operate. For example, the cost of purchasing real estate upon which a plant will be built is a nonrecurring cost, as the cost of constructing the plant itself. Cannot be tied to Quantity.**

Cost Terminology

- ***Direct Costs*** **are those costs that can be reasonably measured and allocated to a specific output/product or work activity.**
  - **Typical direct costs include the labor and material costs directly associated with a product, service, or construction activity.**

- ***Indirect Costs*** **are those costs that are difficult to attribute or allocate to a specific output or work activity. Costs that involve too much effort to allocate directly to a specific output; instead, they are allocated through a selected formula (i.e., proportional to direct labor hours or direct material dollars). Cannot be tied to a specific product.**
  - **Typical indirect costs include the costs of common tools, general supplies, equipment maintenance**

Cost Terminology

- ***Fixed Costs*** **are those costs which are unaffected by changes in output quantity over a feasible range of operations for the available production capability.**
  - **Typical fixed costs include insurance and taxes on facilities, general management and administrative salaries, license fees, and interest costs on borrowed capital. These are Non-Recurring Costs.**

- ***Variable Costs*** **are those costs associated with production that vary with quantity of output. Variable costs are the primary costs that should be considered when making an economic analysis of a proposed change to an existing operation.**
  - **Typical variable costs include material and labor; these are Recurring Costs.**

Cost Terminology

- ***Overhead Costs*** **consist of plant operating costs that are not direct labor or direct material costs. (Indirect costs, overhead, and burden are terms that are sometimes used interchangeably).**
  - **Typical overhead costs include electricity, general repairs, property taxes, supervision**
  - **Various methods are used to allocate overhead costs among products, services, or activities.**
    - » **Most commonly used methods involve allocation in proportion to direct labor costs, direct labor hours, direct materials costs, the sum of direct labor and material costs, or machine hours. (refer to example)**

Cost Terminology

- ***Sunk Costs*** **are those costs that have occurred in the past and have no relevance to estimates of future costs and revenues for alternative course of action.**
  - **Common to all alternatives, not part of prospective cash flows in the future**
  - **Can be disregarded in cost analysis**

- ***Opportunity Costs*** **are those costs incurred because of the use of a limited resource. The opportunity to uses that same resource to monetary advantage in an alternative use is foregone.**
  - **The cost of the best rejected or foregone opportunity**
  - **Often hidden or implied**

Cost Terminology

- ***Standard Costs*** **are representative costs per unit of output that are established in advance of actual production or delivery – "Expected" or "Pre-Determined" Cost**
  - **Developed from the direct labor hours, materials, and support functions (with their established costs per unit) planned for the production or delivery process.**
  - **Play an important role in cost management/control. Representative uses include:**
    - » **estimating future manufacturing or service delivery costs**
    - » **measuring operating performance by comparing actual cost/unit with the standard unit cost**
    - » **preparing bids on products or services**
    - » **establishing the value of work-in-progress and finished inventories**

Cost Terminology

- ***Life-Cycle Cost:*** **the Total Cost of the Acquisition and Ownership of a System over its complete Life Cycle. (diagram)**
  - **Begin with the identification of the requirement for the system and end with its retirement and disposal costs.**
  - **Time horizon is situation-specific and may be projected on a functional or economic basis.**
  - **DoD life-cycle costs can be decomposed into the following sub-categories:**
    - » **development costs**
    - » **flyaway costs**
    - » **weapon system costs**
    - » **procurement costs**
    - » **program acquisition costs**